10/576826
IAP12 Rec'd PCT/PTO 24 APR 2006



# Method and apparatus for separating air by cryogenic distillation

The present invention relates to a method and an apparatus for separating air by cryogenic distillation. In particular, it relates to an air separation method using a mixing column to produce impure oxygen gas.

EP A 0538118 teaches the use of a double column and a mixing column to produce impure oxygen, with a dedicated air booster to compress the air to the pressure of the mixing column.

The object of the present invention is to reduce the investment costs of such an apparatus.

According to one object, the invention provides a method for separating air by cryogenic distillation in an installation comprising a medium-pressure column, a low-pressure column and a mixing column in which:

(i) air is compressed in a compressor, cooled in a heat exchange line and a first portion of the air is sent to the vessel of the mixing column;

(ii) a second portion of the air is sent to the medium-pressure column where it is separated;

(iii) an oxygen-enriched liquid and a nitrogen-enriched liquid are sent from the medium-pressure column to the low-pressure column;

(iv) an oxygen-enriched liquid is sent from the low-pressure column to the top of the mixing column;

(v) at least one flow of liquid is drawn off from the medium or low-pressure column;

(vi) the second portion of the air is boosted in a booster, cooled in the heat exchange line, and divided into a first fraction and a second fraction;

(vii) the first fraction of the air is cooled in the heat exchange line, at least partially liquefied,

and sent to the medium-pressure column and/or the low-pressure column;

(viii) the second fraction of the air is expanded in a Claude turbine and sent to the medium-pressure column; and

(ix) an oxygen-rich flow is drawn off from the mixing column and heated in the heat exchange line.

According to other optional aspects:

- the liquid drawn off from the medium or low-pressure column is an end product;
- the booster is coupled to the Claude turbine;
- the booster is a cold booster;
- the mixing column operates at between 8 and 20 bar abs.;
- all the air sent for distillation is compressed to between 8 and 20 bar abs.;
- between 40 and 90% of the air sent for distillation is boosted;
- the boosted air is boosted to between 12 and 30 bar abs.

According to another aspect, the invention provides an installation for separating air by cryogenic distillation in an apparatus comprising a medium-pressure column, a low-pressure column and a mixing column, a Claude turbine, a booster, means for compressing air, means for sending a portion of the compressed air of the air to the mixing column, means for sending another portion of the compressed air to the booster, means for sending a fraction of the boosted air to the Claude turbine and for sending the expanded air to the medium-pressure column, means for sending the rest of the boosted air to the medium pressure and/or low-pressure column after liquefaction and expansion, and means for drawing off at least one liquid from the medium-pressure column and/or the low-pressure column as end product.

The booster may be coupled to the Claude turbine.

One embodiment of the invention will now be described with reference to the drawing appended hereto, in which figure 1 schematically shows an embodiment of the air distillation installation according to the invention.

The air distillation installation shown in figure 1 is designed to produce impure oxygen OI, for example having a purity of 80 to 97% and preferably of 85 to 95% under a defined pressure P that is substantially different from $6\times10^5$ Pa abs., for example under 8 to $20\times10^5$ Pa. The installation essentially comprises a heat exchange line 1, a double distillation column itself comprising a medium-pressure column 3, a low-pressure column 4 and a main condenser-reboiler 5, and a mixing column 6. The mixing column 6 and the low-pressure column 4 are incorporated in a single structure. The medium-pressure column 3 forms a separate structure and is surmounted by the condenser-reboiler 5, as described in EP A 1978212. The columns 3 and 4 typically operate under about $6\times10^5$ Pa and at about $1\times10^5$ Pa respectively.

As explained in detail in document US A 4 022 030, a mixing column is a column that has the same structure as a distillation column but is used for mixing a relatively volatile gas, introduced at its base, and a less volatile liquid, introduced at its top, under conditions approaching reversibility.

Such a mixture produces cooling energy and therefore serves to reduce the energy consumption associated with distillation. In the present case, this mixture is further exploited to directly produce impure oxygen under the pressure P, as described below.

The air to be separated by distillation is compressed to $15\times10^5$ Pa (generally between 8 and $20\times10^5$ Pa) in a

compressor C01 and suitably cleansed, and divided into two. One portion of this air, accounting for between 40 and 90% of the air, is boosted in a booster 8 to a pressure of between 12 and $30\times10^5$ Pa, cooled in the heat exchange line 1 and divided into two fractions. One fraction continues to be cooled in the heat exchange line 1 where it liquefies at least partially before being introduced into the medium-pressure column 3 via a line 7. A portion or all of this liquefied air may be sent to the low-pressure column 4. Another fraction of the air boosted in 8 and then cooled, is expanded to the medium pressure in a Claude turbine 9 coupled to the booster 8, and then sent to the bottom of the medium-pressure column 3 in gaseous form, a few trays below the inlet point of the line 7. "Rich liquid" (oxygen-enriched air), drawn off from the bottom of the column 3, is expanded in a relief valve 10 and introduced into the column 4. "Poor liquid" (impure nitrogen) 11 drawn off at the top of the column 3 is expanded in a relief valve 12 and introduced at the top of the column 4, and the gas produced at the top of the column 4 constituting the waste gas N1 of the installation is heated in the heat exchange line 1 and discharged from the installation.

Liquid oxygen, more or less pure according to the settings of the double column, is drawn off at the bottom of the column 4, and sent via the line 24 to the condenser-reboiler 5, where it is partially vaporized to form a gas 25 that is sent to the low-pressure column 4. Liquid 26 is drawn off from the condenser 5, compressed by a pump 13 to a pressure P1, slightly higher than the abovementioned pressure P to compensate for pressure drops (P1-P less than $1\times10^5$ Pa), and partly introduced at the top of the column 6. A portion 27 of the liquid oxygen can be sent to a storage unit. Auxiliary air from the compressor C01, compressed to a pressure substantially above the medium pressure and partially cooled in the heat exchange line 1, is

introduced at the base of the mixing column 6. Three liquid streams are drawn off from this column: at its base, liquid similar to the rich liquid and combined with it via a line 15 provided with a relief valve 15A; at an intermediate point, a mixture essentially consisting of oxygen and nitrogen, which is sent to an intermediate point of the low-pressure column 4, via a line 16 provided with a relief valve 17; and at its top, impure oxygen which, after heating in the heat exchange line, is removed, substantially at the pressure P, from the installation via a line 18 as producer gas OI.

A liquid nitrogen flow is drawn off at the top of the medium-pressure column 3 as end product.

Figure 1 also shows auxiliary heat exchangers 19, 20 for recovering the cold available in the fluids flowing in the installation.

It can be readily understood that the double column comprising the columns 3 and 4 can conventionally form a single structure, while the mixing column 6 forms a separate structure.

Optionally, a flow of pressurized liquid oxygen and/or a flow of pressurized liquid nitrogen may be vaporized in the heat exchange line 1 or in a dedicated reboiler.